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BARNACLES (CIRRIPEDIA: BALANIDAE) FROM THE LOWER PLEISTOCENE JAMES CITY FORMATION, NORTH CAROLINA COASTAL PLAIN, WITH THE DESCRIPTION OF A NEW SPECIES OF *BALANUS* DA COSTA

Victor A. Zullo and William Miller, III

Abstract.—Numerous specimens of *Balanus neusensis,* new species, and *B. improvisus* Darwin, and a few specimens of *B. calidus* Pilsbry occur in association with a *Crepidula fornicata* (Linnaeus) biostrome in the lower Pleistocene James City Formation at Johnson Point, Neuse River, Craven County. *Balanus improvisus* and *B. neusensis* also are reported from an isolated James City outcrop at Dam Creek on the Neuse River and from a tidal inlet deposit of presumed equivalent age at Woodside, Pender County. The extant tropical American and Carolinian species *B. calidus* is common in inner shelf deposits of early Pleistocene age in the Carolinas, whereas the extant North Atlantic species *B. improvisus* is more typically found in younger Pleistocene marginal marine deposits of the region. *Balanus neusensis* appears to be the youngest surviving species of the *B. pacificus* Pilsbry group in the western Atlantic, and a descendent of the Pliocene species *B. oppidieboraci* Ross.

Bulk sediment samples from two localities in the lower Pleistocene James City Formation on the Neuse River, Craven County, North Carolina yielded remains of three species of barnacles (Fig. 1). The samples were taken and processed by Miller as part of a paleoecologic study of the James City fauna (Miller and DuBar, in prep.). The majority of barnacle specimens were associated with a *Crepidula fornicata* (Linnaeus) biostrome at Johnson Point in the type area of the formation (UNCW locality Z-807). The second locality (UNCW locality Z-808) near Dam Creek, is an isolated outcrop of James City sediments that yielded relatively few barnacle remains. The abundance of barnacles at the Johnson Point locality is related to the numerous attachment sites for sessile, epibenthic organisms provided by the large, tabular accumulation of the sedentary epifaunal gastropod *Crepidula fornicata.* Two of the Johnson Point barnacles, *Balanus improvisus* Darwin and *B. calidus* Pilsbry, are extant species with Pleistocene fossil records on the Atlantic coast. The third and most abundant barnacle is a new species that bears considerable superficial resemblance to the extant estuarine Atlantic Coast species *B. eburneus* Gould, but is, rather, related to the *Balanus pacificus* Pilsbry group. Extant members of the *B. pacificus* group are known only from the Pacific basin, but Neogene representatives are known from the Atlantic Coast Pliocene, and *Balanus oppidieboraci* Ross, a likely precursor of the new species, occurs in the Pliocene Yorktown Formation of Virginia.

Only a few specimens of the new species and of *B. improvisus* were identified at the Dam Creek locality. As discussed in the section on paleoenvironments and paleoecology, differences in abundances of barnacle remains at the two sites are related to the location of the two sites within the James City embayment and to concomitant differences in depositional environment. The Johnson Point biostrome accumulated in a relatively high energy, shallow water envi-

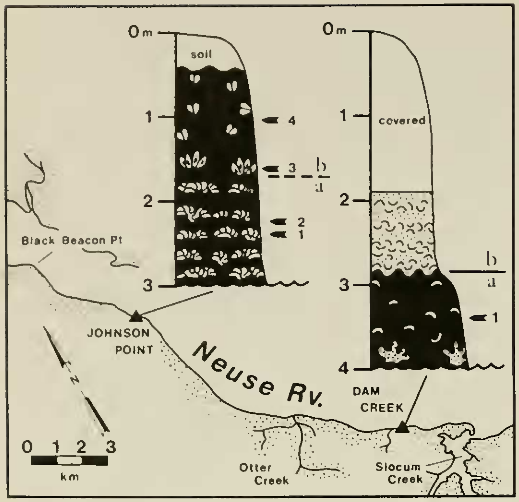


Fig. 1. Location of James City Formation collecting sites on the Neuse River, Craven County, North Carolina.

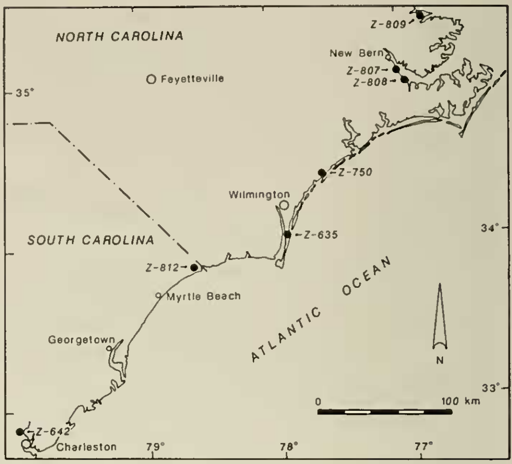


Fig. 2. Location of North and South Carolina Pleistocene sites discussed in text.

ronment where sedimentation rates were low. Barnacles, in addition to requiring the hard substrata for settlement provided by the *Crepidula fornicata* biostrome, are filter feeders that thrive in higher energy sites with little sedimentation. The Dam Creek site, by comparison, represents a deeper water, bay-center deposit where very fine-grained sediments were being deposited and few hard substrata were available. It is likely that the barnacle remains preserved at the Dam Creek locality are allochthonous.

A few, worn, disarticulated specimens of the new species and some juvenile, but well preserved entire individuals of *B. improvisus* were obtained from a tidal inlet deposit of presumed equivalent age at Woodside, Pender County, North Carolina (UNCW locality Z-750; Fig. 2). This is the only other known occurrence of the new species. *Balanus improvisus,* however, is common in later Pleistocene, marginal-marine deposits both in North and South Carolina and is presently found to range from the nearshore subtidal up through the mid-intertidal zone, primarily in marginal-marine environments. To the north of Cape Hatteras, *B. improvisus* is essentially restricted to estuaries (oligohaline through polyhaline), but to the south this species can be abundant in polyhaline and coastal euhaline waters.

Balanus calidus is probably the most commonly encountered barnacle in lower Pleistocene deposits of the Carolinas. Pleistocene examples are usually found in great numbers on shells of *Ostrea sculpturata* Conrad from localities that have been interpreted as representing open water environments or embayments with unrestricted circulation (e.g., Lee Creek Mine, Beaufort County, North Carolina). Extant populations are found in marine waters at subtidal depths and are best developed on the inner and middle shelf.

Stratigraphic Setting

Three lithostratigraphic units crop out along the Neuse River east of New Bern (DuBar and Solliday 1963, Mixon and Pilkey 1976, Miller 1985). These are, in ascending order: 1) lower Pleistocene James City Formation, exposed for the most part along the south shore from Black Beacon Point downstream to Johnson Point; 2) middle Pleistocene Flanner Beach Formation, in bluffs along both sides of the river extending from Johnson Point to the Suffolk (or Grantsboro) Scarp; and 3) upper Pleistocene Core Creek sand, which is poorly exposed downstream from the Suffolk Scarp (Fig. 1). All three units were deposited during glacio-eustatic high stands that occurred at 1,000,000–800,000 yr, 200,000 yr, and 100,000 yr B.P., respectively (McCartan et al. 1982, Cronin et al. 1984).

The oldest Pleistocene depositional cycle is represented by fine-grained, fossiliferous, nearshore marine beds of the James City Formation (DuBar and Solliday 1963, DuBar and Howard 1969, DuBar et al. 1974). The Johnson Point exposure consists of a bluish gray to olive gray, shelly mudstone to siltstone, broadly divisible into a lower bed made up of discontinuous, thin layers of *Crepidula fornicata* shells in life position (stacks of adhering shells) and an upper bed characterized by varied, abundant fossil bivalves, especially *Anadara aequicostata* Conrad, *Ostrea sculpturata* Conrad and *Noetia limula* Conrad. At Dam Creek, slightly over one meter of the James City Formation is overlain disconformably by the Flanner Beach Formation. Here, the James City is a bluish-gray, moderately fossiliferous mudstone to claystone containing valves of the small bivalve *Nuculana acuta* (Conrad). Near the base of the outcrop, heads of the ahermatypic coral *Septastrea* occur in apparent life position (Miller 1985:120).

The James City beds, both at Johnson Point and Dam Creek, were deposited as muddy, more or less shelly sediments within a protected, subtropical marine embayment. Johnson Point appears to be part of a regressive sequence, with deeper subtidal deposits containing the *Crepidula* bank fauna succeeded in the section by shallower subtidal deposits containing a great variety of mollusks and other organisms. Dam Creek seems to be a deeper, bay-center deposit that accumulated basinward of the Johnson Point sequence.

Presumably contemporaneous, sandy, open marine beds are exposed 40 km north of the Neuse River in the Lee Creek Mine at Aurora (referred to as "Croatan Formation" by many workers; see contributions in Ray 1983). The exact temporal and paleogeographic relationships between the James City Formation in the Neuse River Valley area and the Waccamaw Formation in southeastern North Carolina and northeastern South Carolina, traditionally regarded as coeval units, are far from being clear. A recent interpretation based on multiple lines of evidence suggests that the James City Formation may be a little younger than most of the Waccamaw (Cronin et al. 1984).

Paleoenvironments and Paleocommunities

Table 1 lists the most abundant autochthonous invertebrate fossils in samples collected from Johnson Point and Dam Creek. This list gives a general sense of the benthic paleocommunity contexts for balanids living in James City depositional environments. A part of this ecosystem-level context at Johnson Point included long-term community replacement resulting from sustained, unidirectional habitat alteration in subevolutionary time (Miller 1986). The faunal transition at Johnson Point involved the fairly abrupt decline of the biostrome and its replacement by a more diverse, level-bottom community with many infaunal, suspension-feeding bivalves, carnivorous and scavenging gastropods, and occasional clumps of oysters.

Little is known about the conditions conducive to extensive buildups of *C. fornicata* into banks the size of the Johnson Point biostrome, which is estimated to have covered up to 15,000 m^2 of sea floor during maximum development (Miller and DuBar, in prep.). A long period of low turbidity, consistent currents carrying food supplies, and near-normal marine salinity probably were key factors (see Johnson 1972, DuBar et al. 1974:111, Hoagland 1979). Changes in currents, probable shallowing in the Johnson Point area, and a shift in local disturbance regime (seasonality, frequency, intensity, and geographic extent of physical disturbance; see Sousa 1985, Connell and

Table 1.—Most important components of fossil associations from the James City Formation in the Neuse valley. Only organisms with individuals making up ≥0.5% of the association are listed. Format includes taxon, relative abundance, followed by organism type/substrate niche + feeding category. All abbreviations explained at foot of table; sample numbers refer to Fig. 1.

I. *Crepidula* biostrome association (Johnson Point, samples 1 and 2)		
*Crepidula fornicata**	43.2%	Ga/EPSF
Boonea seminuda	29.5	Ga/EPPA
Balanus spp.	8.6	Ci/EPSF
Nuculana acuta	4.8	Bi/INDF
Ostrea sculpturata	4.3	Bi/EPSF
Anadara aequicostata	2.3	Bi/INSF
Anachis lafresnayi var.	1.5	Ga/VAGC
A. obesa	1.5	Ga/VAGC
Nassarius albus	0.8	Ga/VAGS
II. *Ostrea* clump association (Johnson Point, sample 3)		
Crepidula fornicata	30.2%	Ga/EPSF
Boonea seminuda	27.9	Ga/EPPA
Balanus spp.	10.8	Ci/EPSF
Nuculana acuta	7.4	Bi/INDF
*Ostrea sculpturata**	6.7	Bi/EPSF
Anadara aequicostata	2.7	Bi/INSF
Mulinia lateralis	1.2	Bi/INSF
Turbonilla (*Chemnitzia*) sp.	1.1	Ga/EPPA
Sphenia sp.	1.1	Bi/INSF?
Boonea impressa	1.1	Ga/EPPA
Anachis obesa	1.0	Ga/VAGC
A. lafresnayi var.	0.9	Ga/VAGC
Mercenaria sp. cf. *M. permagna*	0.7	Bi/INSF
Abra aequalis	0.7	Ga/VAGC
Urosalpinx perrugata	0.7	Ga/VAGS
Busycon sp.	0.6	Ga/VAGS
Nassarius albus	0.6	Ga/VAGS
brachyurans	0.5	Ma/VAGS
III. *Anadara-Noetia* association (Johnson Point, sample 4)		
Crepidula fornicata	17.8%	Ga/EPSF
Boonea seminuda	17.2	Ga/EPPA
Ostrea sculpturata	11.9	Bi/EPSF
Nuculana acuta	11.4	Bi/INDF
Balanus spp.	8.7	Ci/EPSF

Table 1.—Continued.

*Anadara aequicostata**	8.0	Bi/INSF
Abra aequalis	4.4	Bi/INDF
Sphenia sp.	2.1	Bi/INSF?
brachyurans	1.5	Ma/VAGS
Anachis lafresnayi	1.5	Ga/VAGS
Boonea impressa	1.4	Ga/EPPA
Cumingia tellinoides	1.1	Bi/INSF
Mercenaria sp. cf. *M. permagna*	1.1	Bi/INSF
Mulinia lateralis	0.9	Bi/INSF
Turbonilla (*Pyrgiscus*) sp.	0.9	Ga/EPPA
Anachis obesa	0.8	Ga/VAGC
Turbonilla (*Chemnitzia*) sp.	0.7	Ga/EPPA
Melanella conoidea	0.7	Ga/VAGU
Urosalpinx perrugata	0.7	Ga/VAGC
Nucula proxima	0.6	Bi/INDF
Nassarius albus	0.6	Ga/VAGS
Polinices sp.	0.5	Ga/VAGC
Prunum sp.	0.5	Ga/VAGU
*Noetia limula**	0.5	Bi/INSF
Vermicularia sp. cf. *V. knorri*	0.5	Ga/EPSF?
IV. *Nuculana* association (Dam Creek)		
*Nuculana acuta**	61.3%	Bi/INDF
Mulinia lateralis	24.2	Bi/INSF
Parvilucina multilineata	4.0	Bi/INSF
Abra aequalis	2.1	Bi/INDF
Anadara aequicostata	1.1	Bi/INSF
Crassinella lunulata	1.1	Bi/INSF
Ensis sp.	1.0	Bi/INSF
Balanus spp.	1.0	Ci/EPSF
Prunum sp.	0.7	Ga/VAGU
Vermicularis sp. cf. *V. knorri*	0.5	Ga/EPSF?
Ostrea sp.	0.5	Bi/EPSF
Gemma gemma	0.5	Bi/INSF

Symbols used in table: *—dominant organism in terms of biovolume; lends name to association. Organism type: Bi—bivalve mollusk, Ga—gastropod mollusk, Ci—cirriped crustacean, Ma—malacostracan crustacean. Substrate niche + feeding category: INSF—infaunal suspension-feeder, INDF—infaunal deposit-feeder, EPSF—epifaunal suspension-feeder, EPPA—epifaunal parasite, VAGC—vagrant carnivore, VAGS—vagrant scavenger, U—unknown.

Keough 1985) led to disruption of the *Crepidula*-dominated community and establishment of the community represented by the *Ostrea* clump and *Anadara-Noetia* fossil associations (Table 1). In terms of changing spatial patterns, laterally extensive blankets of *Crepidula* stacks gave way to a much patchier and consequently more diverse community with only a few isolated *Crepidula* aggregations persisting in the area. Although barnacles are abundant throughout the transition sequence, they are more numerous in shelly beds within the biostrome probably because of widespread availability of hard substrata in the form of exposed *Crepidula* shells.

By comparison, balanids are uncommon at Dam Creek (Table 1) in a fossil association dominated by the infaunal, deposit-feeding bivalve *Nuculana acuta*. This association was derived from a deeper subtidal community inhabiting a very fine-grained, soft to possibly thixotropic bottom, offshore from the *Crepidula* biostrome and *Anadara-Noetia-Ostrea* paleocommunities (see Parker 1976).

Locality Descriptions

University of North Carolina at Wilmington (UNCW):

Z-635 Cape Fear coquina, south side of Snows Cut, 650 m west of U.S. Highway 421 bridge over Atlantic Intracoastal Waterway, southern New Hanover County, North Carolina. V. Zullo, coll., 5 Sep 1980.

Z-642 Upper Pleistocene shell bed in borrow pit (since reclaimed) for construction of Mark Clark Expressway, on north side of Ashley Hall Road, 1370 m east of intersection with State Highway 61 (Ashley River Road) and west of Ashley River, Charleston County, South Carolina. V. Zullo, coll., 7 Feb 1981.

Z-750 Waccamaw Formation, quarry at seaward edge of +7.6 m terrace, southeast of U.S. Highway 17 at Woodside, Pender County, North Carolina. V. Zullo, coll., 26 Jun 1985.

Z-807 James City Formation, north side of Johnson Point in steep-sided bank, 500 m upstream (northwest) from tip of point and 400 m downstream (southeast) from pier at Veterans of Foreign Wars building, south shore of Neuse River, Craven County, North Carolina. W. Miller, coll., Aug 1982.

Z-808 James City Formation, basal bed in low bank 3.8 km upstream (northwest) from mouth of Slocum Creek and 700 m downstream (southeast) from mouth of Dam Creek, south shore of Neuse River, Craven County, North Carolina. W. Miller, coll., Aug 1982.

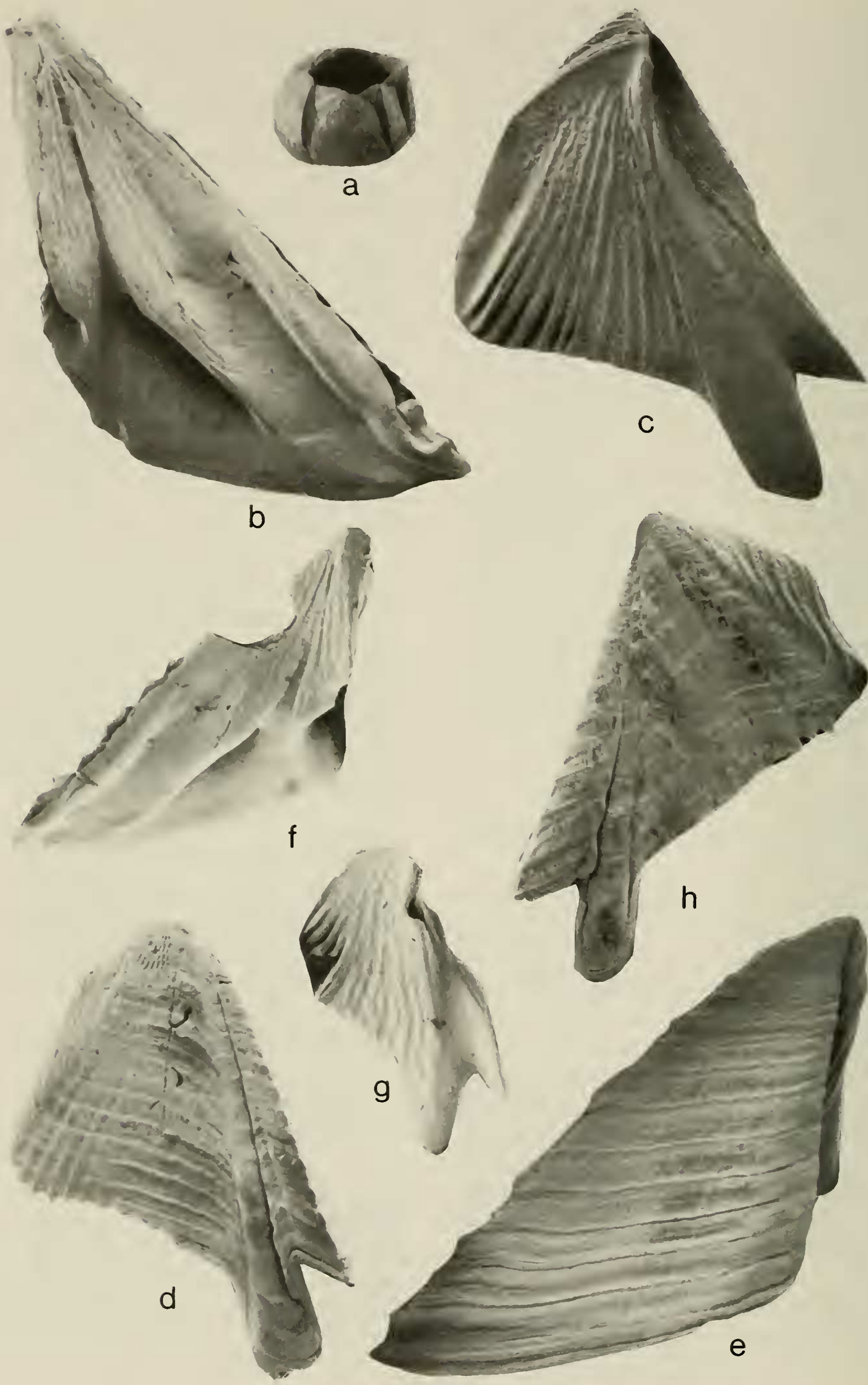
Z-809 "Croatan Sand," Lee Creek Mine, south shore of the Pamlico River, Richland Township, north of Aurora, Beaufort County, North Carolina. Aura Baker, coll., date unknown.

Z-812 Waccamaw Formation, Cedar Creek Village quarry, southeast side of U.S. Highway 17, Little River, Horry County, South Carolina. V. Zullo and W. B. Harris, coll., 1977.

Systematic Paleontology

Suborder Balanomorpha Pilsbry, 1916
Superfamily Balanoidea Leach, sensu Newman and Ross, 1976
Family Balanidae Leach, sensu Newman and Ross, 1976
Subfamily Balaninae Leach, sensu Newman, 1980
Genus *Balanus* Da Costa, 1778
Balanus improvisus Darwin, 1854
Fig. 3

Balanus improvisus Darwin, 1854:250, pl. 6, fig. 1a–c; Pilsbry, 1916:84, text fig. 16a, pl. 24, figs. 3–3b, 5–5d; Henry and McLaughlin, 1975:68, text fig. 16, pl. 5, figs. a–f, g, h–j (see for complete synonymy).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Material examined.—Johnson Point, Neuse River, UNCW locality Z-807: 16 complete shells, over 200 compartmental plates, over 50 opercular plates.—Dam Creek, Neuse River, UNCW locality Z-808: 18 compartmental plates, 1 scutum.—Woodside, Pender County, UNCW locality Z-750: 6 shells, some with opercular plates, 8 isolated scuta, 3 isolated terga.—Snows Cut, New Hanover County, UNCW locality Z-635: 7 shells, 3 scuta, 5 terga.—Charleston County, South Carolina, UNCW locality Z-642: 9 compartmental plates, 1 tergum.

Disposition of specimens.—Figured hypotypes USNM 405359 through 405365 are in the collection of the Department of Paleobiology, National Museum of Natural History, Washington, D.C. Remaining specimens are in the collection of the Department of Earth Sciences, University of North Carolina at Wilmington.

Geologic and geographic range.—Recent: Scotland and Baltic Sea to West Africa; Mediterranean, Black, Caspian and Red seas; Nova Scotia to Patagonia; Oregon to Peru; Japan; Australia (Henry and McLaughlin 1975). Documented fossil occurrences: Pleistocene, North and South Carolina.

Discussion.—*Balanus improvisus* is a common element of estuarine faunas of the North Atlantic basin, and has been introduced to various localities throughout the world by ships. Fossils of this species have not been reported previously from the East Coast of North America. Kolosváry (1955, 1959, 1961a, b) cited *B. improvisus* from the Miocene (Burdigalian and Tortonian) of Hungary and the USSR without accompanying descriptions or illustrations of the specimens. Because of the antiquity of this extant species suggested by these records, and because of the distance of these localities from the known natural range of *B. improvisus,* Kolosváry's identifications are in doubt.

The specimens from the James City Formation and from Woodside are typical for the species, which is identified by: (1) its narrow radii with nonseptate sutural edges; (2) its scutum which lacks external radial striae and bears a well-developed adductor ridge; and (3) its tergum with its long, very narrow tergal spur and partially infolded spur furrow. *Balanus improvisus* is also known from late Pleistocene deposits in the Carolinas, including the Cape Fear "coquina" in southern New Hanover County, North Carolina (UNCW locality Z-635) and an upper Pleistocene shell bed northwest of Charleston, South Carolina (UNCW locality Z-642; Zullo 1986).

Balanus neusensis, new species
Figs. 4a–e, 5, 6

Holotype.—Shell with opercular plates, USNM 405366.

Type locality.—*Crepidula fornicata* biostrome, UNCW locality Z-807, James City Formation, Johnson Point, Neuse River, Craven County, North Carolina.

Diagnosis.—Smooth to irregularly plicate, high conic shell with moderately-toothed, subtriangular orifice and broad radii with oblique, crenate summits; parietal tubes open throughout; basis porous, pores not septate; scutum very narrow, with prominent radial striae, markedly denticu-

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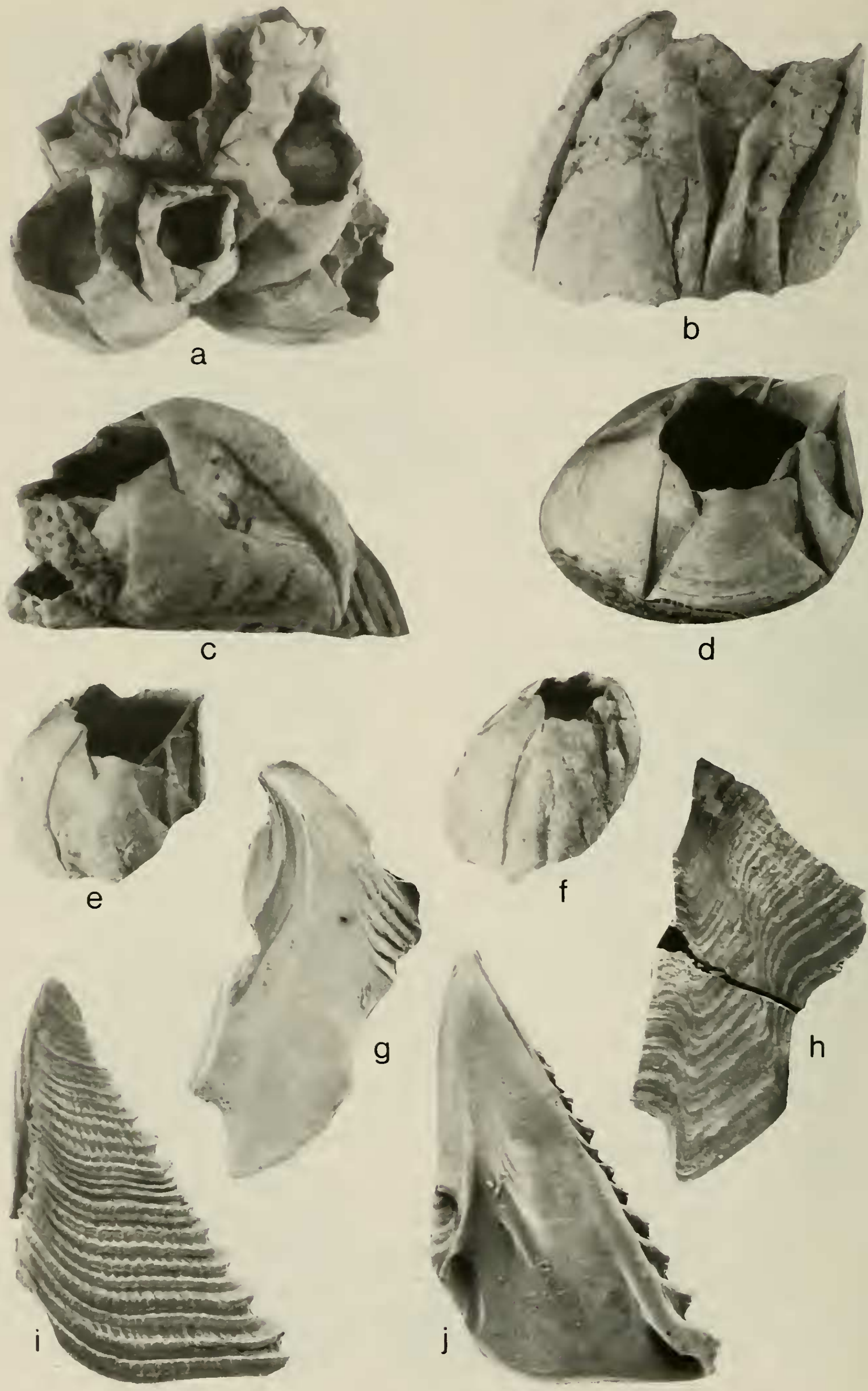
Fig. 3. *Balanus improvisus*: a, Side view of shell, hypotype USNM 405359, ×3; b, Interior of scutum, hypotype USNM 405360, ×18; c, Interior of tergum, hypotype USNM 405361, ×21; d, Exterior of tergum, hypotype USNM 405362, ×21; e, Exterior of scutum, hypotype USNM 405363, ×25; f, g, Interiors of scutum and tergum, hypotype USNM 405364, ×37; h, Exterior of tergum, hypotype USNM 405365, ×33. Figures a–e, UNCW locality Z-807, Johnson Point; f, g, UNCW locality Z-750, Woodside; h, UNCW locality Z-642, Charleston.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late occludent margin, prominent, high adductor ridge extending nearly from apex to basal margin and separated from erect articular ridge by deep, narrow cleft; tergum relatively narrow, with infolded, partially closed spur furrow and short, narrow spur placed its own width from basiscutal angle; basal margin of tergum not embayed on carinal side.

Description.—Shell (Figs. 4a–e, 5d–g) of moderate size (largest 2.4 cm in height and 2 cm in greatest basal diameter), high conic to subcylindric, with large, moderately-toothed, subtriangular orifice; parietes smooth or irregularly plicate, plications reflecting irregularities of substratum; radii thick, solid, moderately broad, glossy, horizontally striate, with roughly crenulated summits sloping about 30° from horizontal; sutural edges of radii septate, with prominent denticulae on lower sides of septa; edges of parietes receiving sutural edges of radii also septate, with denticulae on upper sides of septa; alae thick, broad, short, with moderately convex summits and finely-septate sutural edges; sheath solid, short, confined to upper third of interior of shell; basal margin of sheath thin, dependent, forming deep, narrow, non-vesiculate cavity between edge of sheath and interior of parietes; interior of parietes strongly and regularly ribbed near base, ribs fading towards base of sheath; internal ribs conforming to parietal septa; parietal tubes numerous, round to oval, moderately large, open from apex to base; occasional, single, fine, secondary septa extending into parietal tubes from external lamella; basis porous, thin at center, thickening at margin; basal tubes small, non-septate.

Scutum (Figs. 5c, d, g, 6a–c) nearly flat, very narrow, thick; narrow strip of tergal margin sharply reflexed inward at 90°; exterior ornamented by prominent growth ridges (best developed on lower half of plate) that are broken into nodes where they are crossed by deeply incised radial striae on central third of plate; striate central third of plate noticeably sulcate; reflexed tergal margin and narrow strip of plate adjacent to occludent margin without radial striae; major growth ridges extending onto occludent margin to form large, obliquely-inclined occludent teeth; apex and basioccludent angle acute, basitergal angle truncate at about 45°; occludent margin straight; tergal margin straight to slightly convex; basal margin sinuous, with central third convex, reflecting central, external sulcus of plate; length of basal margin no more than one-half length of occludent margin; articular ridge prominent, erect, with broad, flat upper surface, and extending from just below apex of plate to just beyond midpoint of plate; articular furrow moderately broad, deep, crossed by 2 or 3, low, sharp, nearly vertical growth ridges; adductor ridge prominent, highest in center, inclined toward articular ridge, very long, extending from just below upper end of articular ridge nearly to basal margin; adductor ridge not confluent with articular ridge, leaving deep, narrow cleft between ridges extending nearly to apex of plate; adductor muscle pit large, usually deep, oval, located near midpoint of plate between adductor ridge and occludent margin; 2 short, low, thin, nearly equally-spaced, vertical ridges occurring on lower third of interior of scutum between adductor ridge and basitergal angle; ridge closest to truncate basi-

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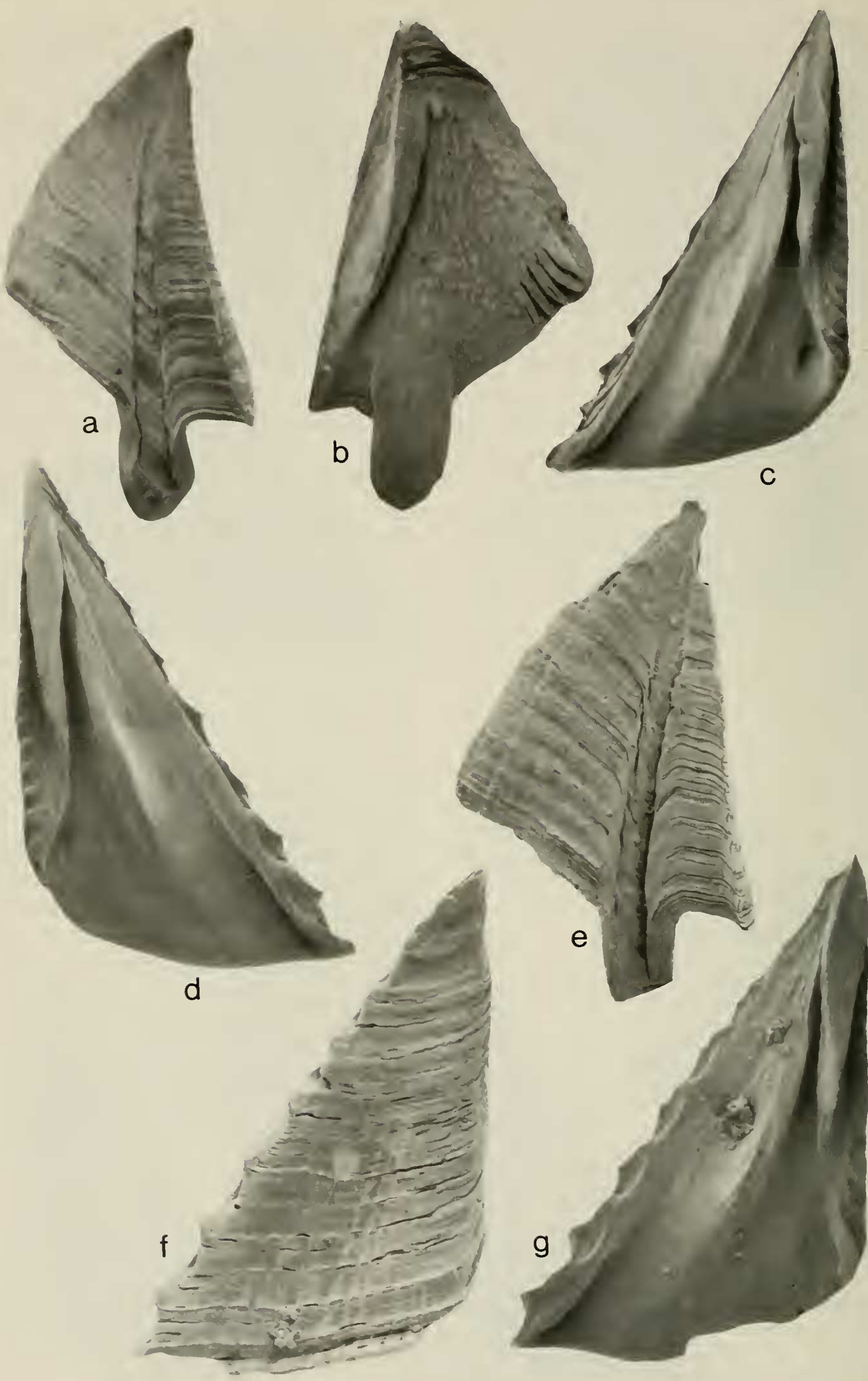
Fig. 4. a–e, *Balanus neusensis,* UNCW locality Z-807, Johnson Point: a, Shell clump, including holotype USNM 405366 (lower center) and paratype lot USNM 405367, ×2; b, Side view of shell, paratype USNM 405368, ×2.4; c, Rostrocarinally elongate shell growing on scutum, paratype USNM 405369, ×6.5; d, Oblique view of shell with convex basis, previously attached to interior of *Crepidula* shell, paratype USNM 405370, ×2.4; e, Oblique view of subcylindric shell, paratype USNM 405371, ×2.4; f–j, *Balanus calidus,* hypotype USNM 405372, UNCW locality Z-807, Johnson Point: f, Oblique view of shell, ×6.5; g, Interior of tergum, ×32; h, Exterior of broken tergum, ×32; i, Exterior of scutum, ×33; j, Interior of scutum, ×33.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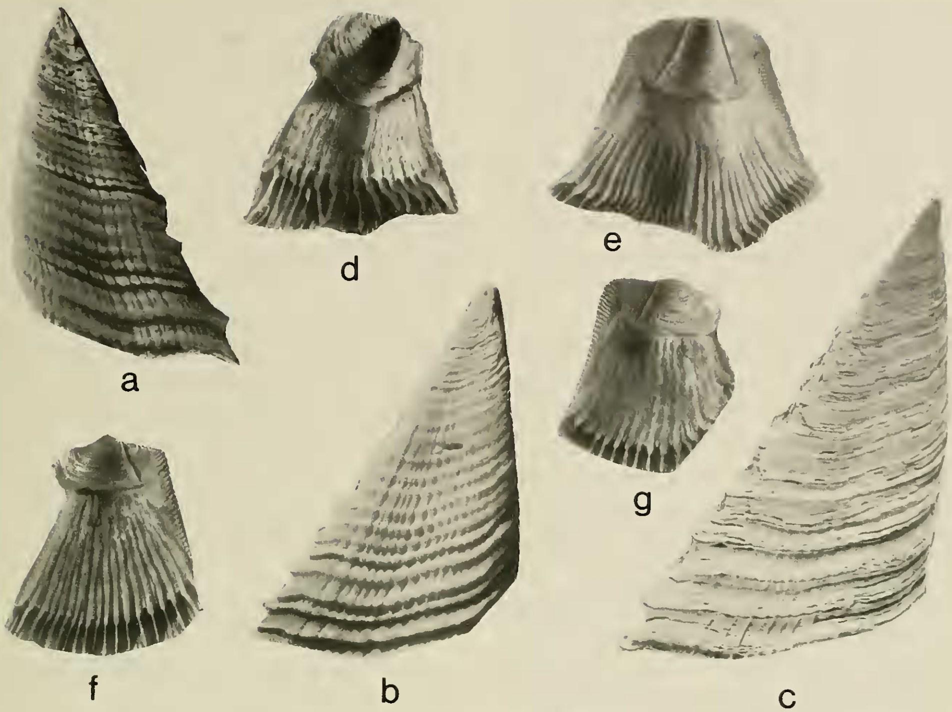

Fig. 6. *Balanus neusensis,* UNCW locality Z-807, Johnson Point. a–c, Exteriors of scuta showing range in development of external radial striae: a, paratype USNM 405377, ×6; b, paratype USNM 405378, ×6; c, paratype 405379, ×12; d, Interior of carina, paratype USNM 405380, ×2.5; e, Interior of rostral plate, paratype USNM 405381, ×2.5; f, Interior of lateral plate, paratype USNM 405382, ×2.5; g, Interior of lateral plate, paratype USNM 405383, ×2.5.

tergal angle forming lateral border of large, deeply impressed, ovoid to triangular, lateral depressor muscle pit situated next to basitergal angle; rostral depressor muscle pit long, narrow; upper part of interior of plate between adductor ridge and occludent border markedly ridged or papillate especially in larger specimens; basal margin of larger specimens nodose, nodes reflecting external radial striae.

Tergum (Figs. 5a–c, e) relatively thin, narrow, with acute apex, slightly concave scutal margin and gently convex carinal margin; basal margin broadly V-shaped; exterior ornamented by low growth ridges crossed by faint radial striae; tergal furrow partially infolded, but open from apex to base of spur; tergal spur narrow, relatively short, straight to slightly arched toward scutum, with parallel sides and gently rounded base; width of spur between one-fifth and one-fourth width of basal margin; distance of spur from basiscutal angle approximately equal to its width; length of spur about one-fifth length of tergum; articular ridge prominent, sharp, arcuate, nearly erect, highest in upper third

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Fig. 5. *Balanus neusensis,* UNCW locality Z-807, Johnson Point: a, Exterior of scutum, paratype USNM 405373, ×13; b, Interior of tergum, paratype USNM 405374, ×13; c, Interior of scutum, paratype USNM 405375, ×12; d, Interior of scutum, paratype USNM 405376, ×14; e–g, Tergum exterior, scutum exterior, scutum interior, holotype USNM 405366, ×18.

of plate, and extending from apex to, or nearly to, basiscutal angle; articular furrow broad, shallow, crossed by 2 or 3 low, sharp, steeply oblique growth ridges; depressor muscle crests well developed, short, increasing in length toward carinal margin, up to 6 in number; interior of tergum between articular ridge and carinal margin markedly rugose, rugosities fading toward basal margin; interior surface of apex marked by sharp, closely-spaced growth ridges.

Material examined.—Johnson Point, Neuse River, UNCW locality 807: 37 complete shells, one with opercular plates; over 1000 compartmental plates, over 500 opercular plates. Dam Creek, Neuse River, UNCW locality 808: 12 compartmental plates, 1 scutum. Woodside, Pender County, UNCW locality Z-750: three worn scuta.

Disposition of types.—Holotype USNM 405366, paratypes USNM 405368–405371 and 405373–405383, and paratype lot 405367 are in the collection of the Department of Paleobiology, National Museum of Natural History, Washington, D.C.

Geologic and geographic distribution.—Early Pleistocene, North Carolina.

Etymology.—The specific name is taken from the Neuse River, which is adjacent to the type locality at Johnson Point, Craven County.

Discussion.—*Balanus neusensis* is typically a robust, thick-walled, conic barnacle. There are, however, some rather odd specimens from the Johnson Point locality that are small (up to 5 mm in greatest basal diameter), laterally asymmetric, and tear-drop shaped, being widest at the rostral, and narrowest at the carinal end (Fig. 4c). These specimens are attached to scuta of *B. neusensis,* and their shape is governed by the form of that plate. Because of the consistency in asymmetry and shell alignment, it is probable that these small barnacles were growing on scuta of living adults.

The shell of *B. neusensis,* in external aspect, bears considerable resemblance to that of the extant western Atlantic species *B. eburneus* Gould, but is readily distinguished by the lack of transverse septa in the parietal and basal tubes, and the solid, rather than vesicular sheath. The scutum of *B. neusensis* also resembles that of *B. eburneus* in bearing prominent external radial striae, but is otherwise quite distinct, being considerably narrower, and in having a much longer and more prominent adductor ridge which is not confluent with the base of the articular ridge. The deep, narrow cleft formed between the adductor and articular ridges is a very distinctive feature of *B. neusensis.* The tergum is very unlike that of *B. eburneus,* having a well-defined, partially infolded spur furrow, and lacking any indication of an embayment on the carinal side of the basal margin.

The shell and opercular plates of *B. neusensis* most closely resemble those of *B. oppidieboraci* Ross from the Pliocene Yorktown Formation of Virginia and its equivalents in the Carolinas (see Ross 1964, Zullo 1986). The shells of the two species are virtually identical in form, but can be distinguished by the summits of the radii. Although Ross (1964:490) described the summits of the radii of *B. oppidieboraci* as varying from 45° to subhorizontal, examination of nearly 100 specimens from the Yorktown Formation of Virginia indicates that oblique radii are very rare in this species and are confined to individual plates of specimens with otherwise subhorizontal summits. The summits of the radii of *B. neusensis,* on the other hand, are always oblique and are, additionally, crenate, whereas those of *B. oppidieboraci* are smooth. The scutum of *B. oppidieboraci* bears finer, more numerous radial striae over almost the entire external surface of the plate, is not sulcate longitudinally, and the growth ridges are not broken into prominent nodes. The articular ridge is reflexed over the articular furrow, and its upper surface is not flattened. The tergum is broader, the tergal spur is broader and longer, and the tergal furrow, although open throughout its length, is narrower as a result of infolding from the sides.

Balanus neusensis and *B. oppidieboraci* appear to be related to species of the *B. amphitrite* Darwin complex and, especially, to the *B. pacificus* Pilsbry group, which is represented in the Virginia Pliocene fauna by *B. pacificus prebrevicalcar* Ross. The *B. pacificus* group is not known in the extant Atlantic fauna, surviving only in the eastern Pacific. It is possible that *B. neusensis* is a derivative of *B. oppidieboraci* and the last survivor of the *B. pacificus* group in the North Atlantic basin.

Balanus calidus Pilsbry, 1916
Fig. 4f–j

Balanus spongicola var. Darwin, 1854:225, pl. 4, fig. 1d.
Balanus calidus Pilsbry, 1916:118, pl. 25, figs. 1–1c, text fig. 32a–f.—Zullo, 1966: 235.—Newman and Ross, 1976:65 (see for complete synonymy).

Material examined.—Johnson Point, Neuse River, UNCW locality Z-807; 2 complete shells (one with opercular plates), 4 compartmental plates.—Lee Creek Mine, Beaufort County, UNCW locality Z-809: over 200 shells on *Ostrea sculpturata,* many with opercular plates.—Waccamaw Fm., Little River, South Carolina, UNCW locality Z-812: over 500 shells on *Ostrea sculpturata,* many with opercular plates.

Disposition of specimens.—Figured hypotype USNM 405372 is in the collection of the Department of Paleobiology, National Museum of Natural History, Washington, D.C. Remaining specimens are in the collection of the Department of Earth Sciences, University of North Carolina at Wilmington.

Geologic and geographic range.—Recent: North Carolina south to the West Indies and the Gulf of Mexico. Pleistocene: North and South Carolina (Wells and Richards 1962; and reported herein); (?) northern Colombia (Nilsson-Cantell 1939). (?) Miocene (Tortonian), Bulgaria (Kolosváry 1962).

Discussion.—*Balanus calidus* was the most common balanoid barnacle on the continental shelf of the Carolinas (Zullo 1966), but in recent years has been replaced by the related tropicopolitan species *B. trigonus* Darwin. There is some suggestion that *B. trigonus* is a recent introduction to the Atlantic coast of the United States (see Wells 1966:84), a suggestion that is supported by the Pleistocene fossil record. *Balanus calidus* is abundant in lower Pleistocene marine deposits of the Carolinas, whereas no specimen of *B. trigonus* has yet been identified positively from the region (see Ross 1965: 273). The Pleistocene shells from the James City Formation have the small orifice, relatively narrow radii and ribbed parietes characteristic of *B. calidus.* The externally striate scutum is rather thick and narrow, and bears a rather short and indistinct adductor ridge. The tergum is distinguished by its broad, basally truncate spur.

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